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Crabtree et al.

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(54) **HINGED JOINT SYSTEM**

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(51) **Int. Cl.**
A61F 2/38 (2006.01)

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USPC **623/20.24**

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See application file for complete search history.

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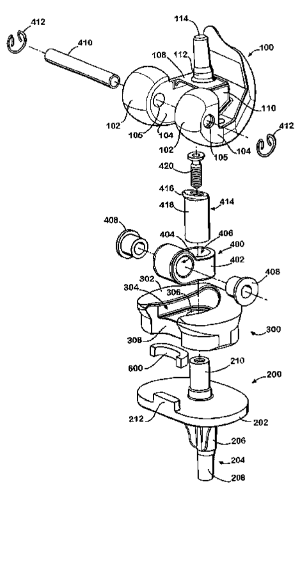
(57) **ABSTRACT**

Methods, systems, and devices for replacement of a joint with a prosthetic system that replicates the natural kinematics of the joint is disclosed. A prosthetic system according to one embodiment includes a tibial component having a tibial plateau and a tibial stem portion, the tibial plateau having a top side and a bottom side, a tibial insert, with a bearing surface, adapted to be positioned on the top side of the tibial plateau, a femoral component having a base portion and a central housing, the femoral component having an axis of extension-flexion rotation, the base portion having a pair of condyles, a mechanical linkage component linking the tibial component with the femoral component and with the tibial insert in between the tibial component and the femoral component, so that there is a center of contact between the condyles and the bearing surface, the mechanical linkage component adapted to allow the center of contact to move posteriorly during flexion, provide for the movement of the axis of extension-flexion rotation in the superior-inferior direction, and allow rotation of the tibial component, the bearing surface, and the femoral component about a superior-inferior axis in order to provide and control the natural kinematics of the knee joint.

21 Claims, 7 Drawing Sheets



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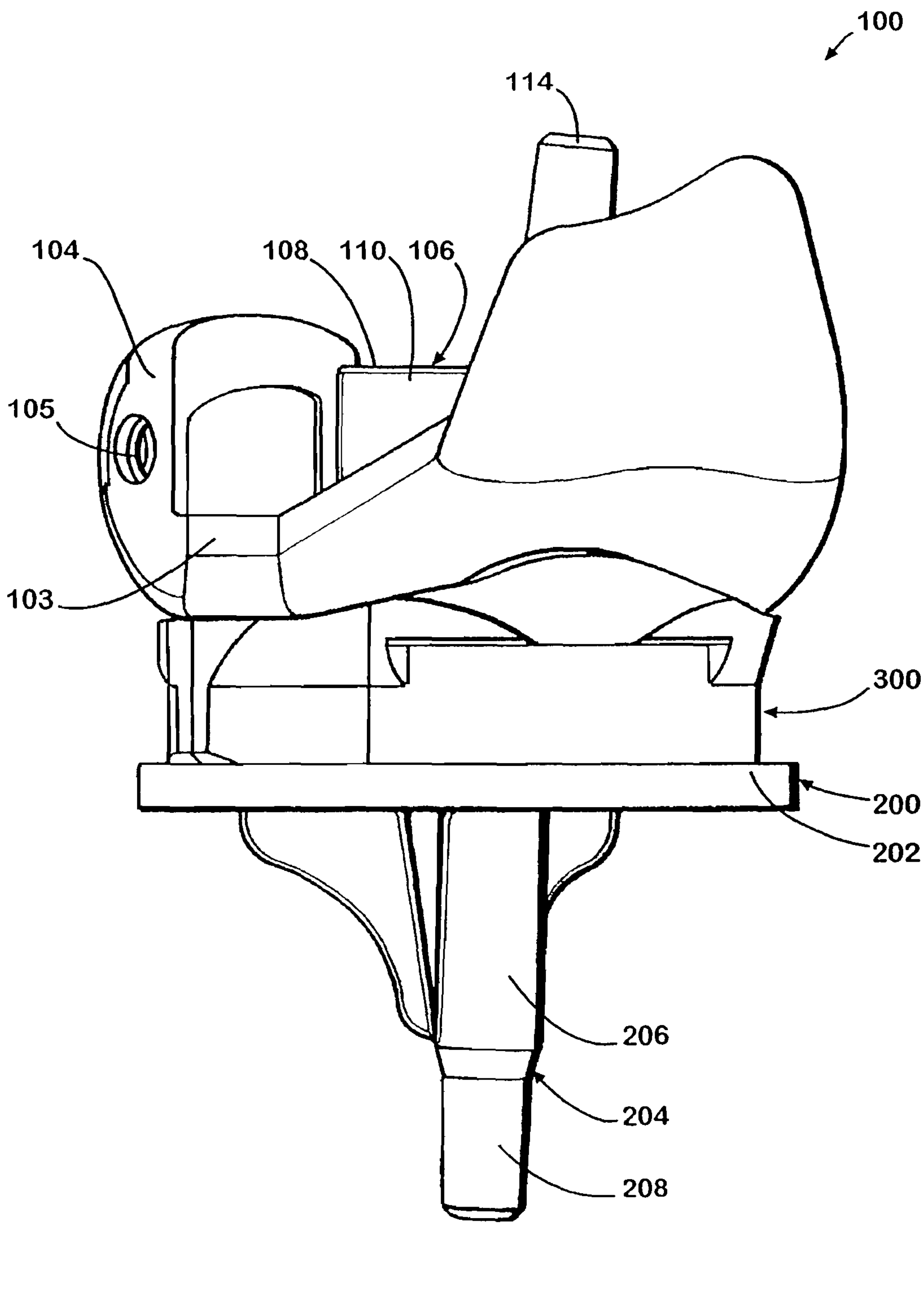

FIG 1A

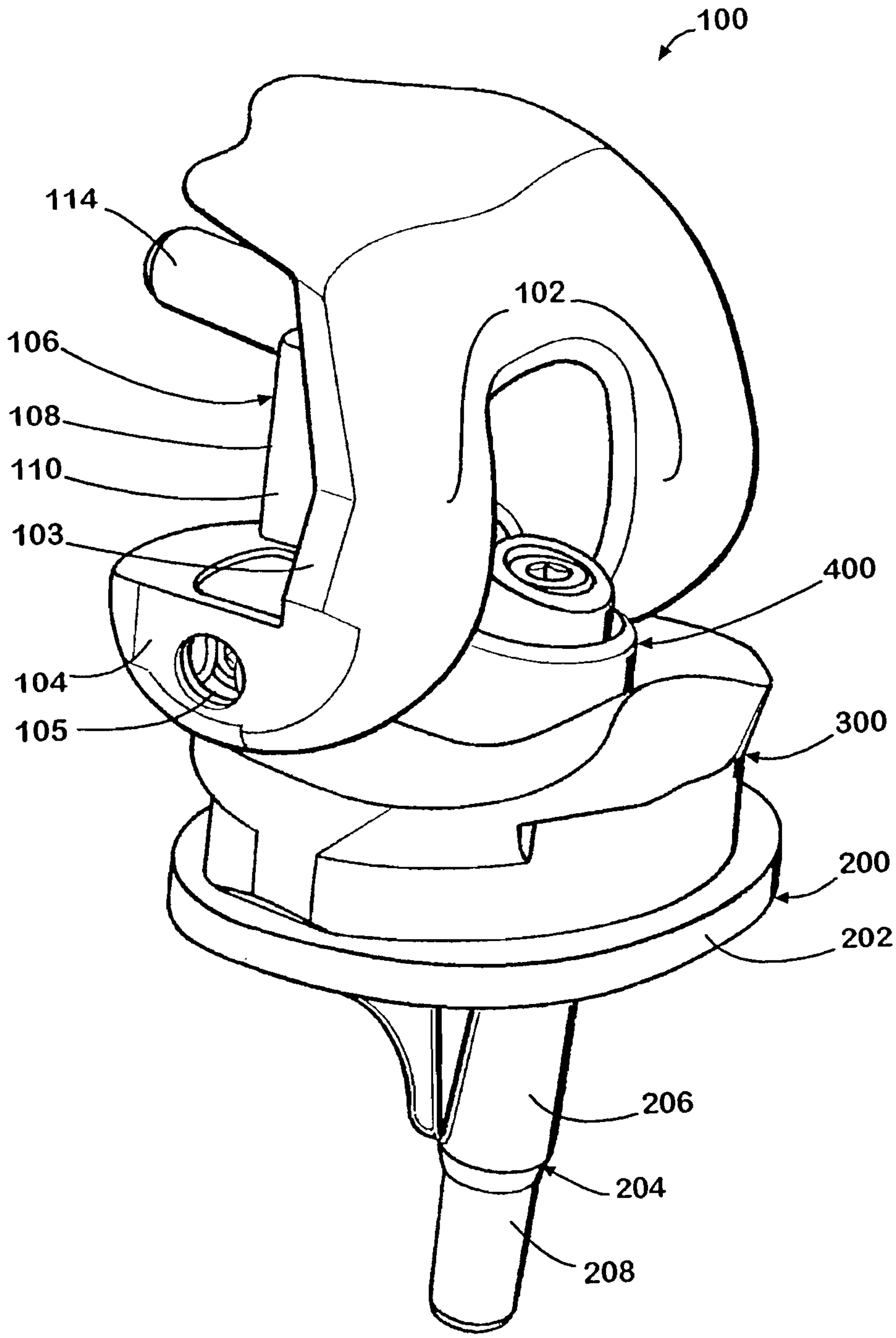

FIG 1B

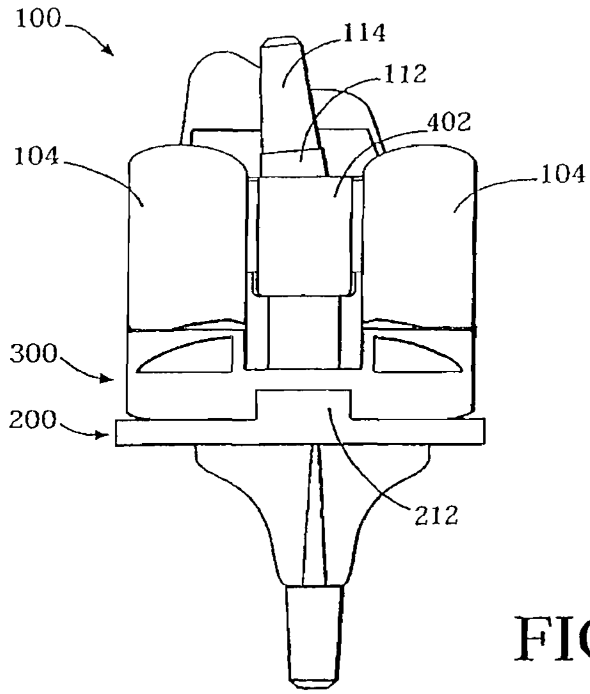

FIG 2

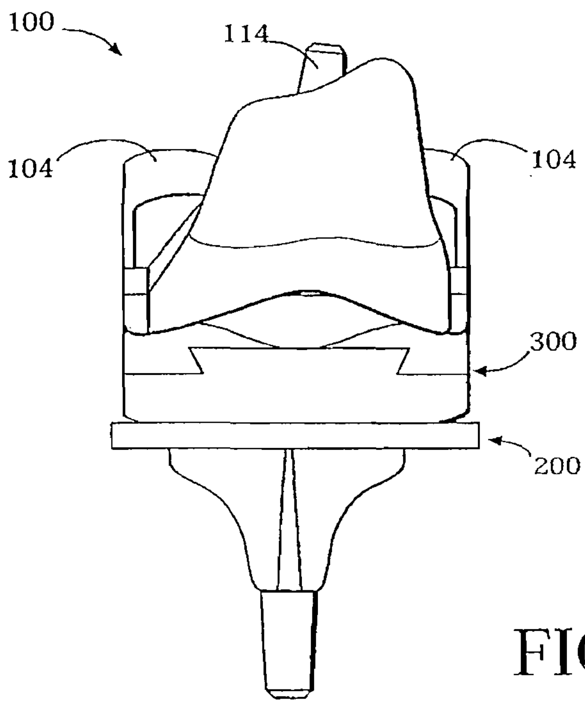

FIG 3

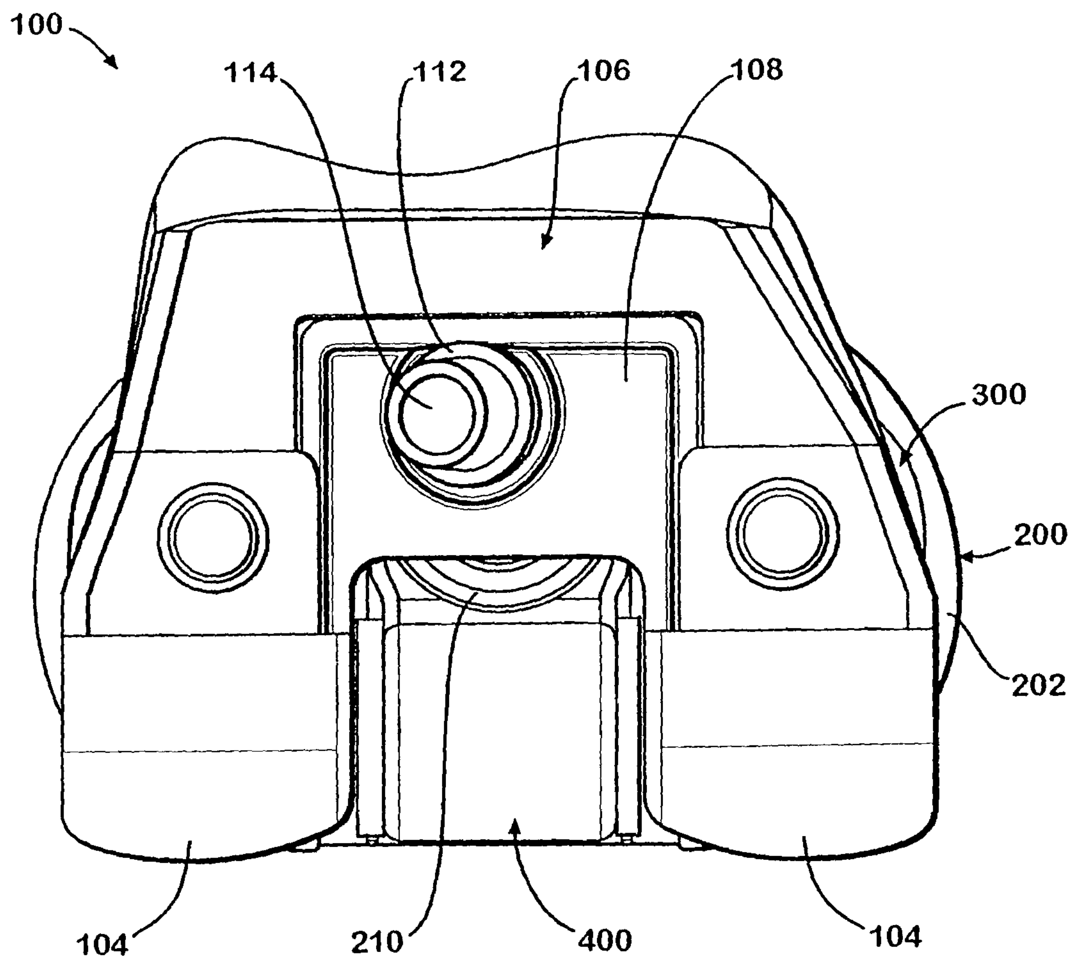

FIG 4

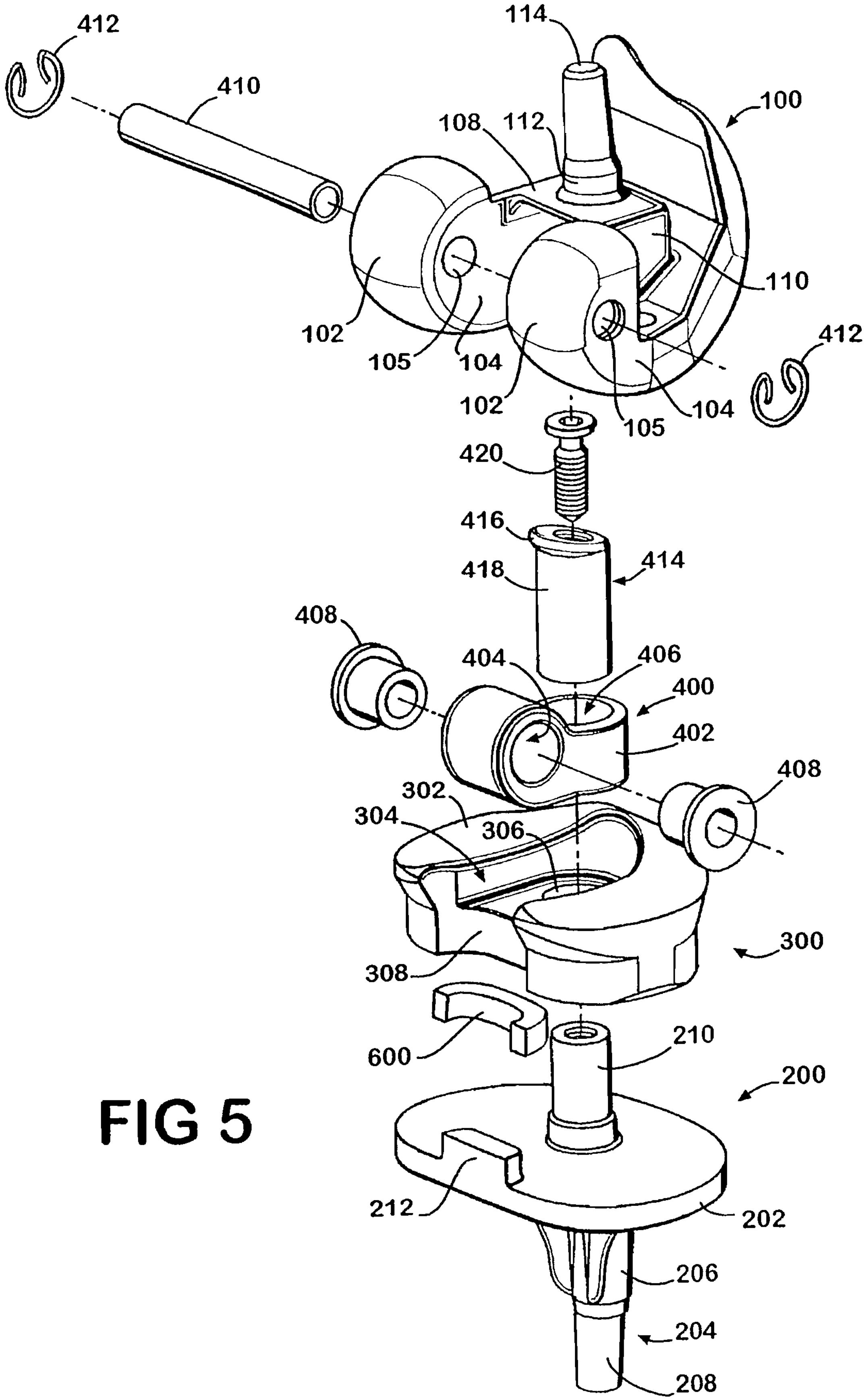
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FIG 5

0° FLEXION

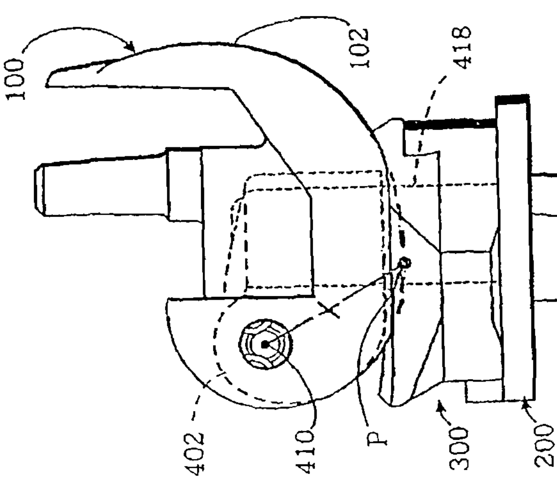

FIG 6A

45° FLEXION

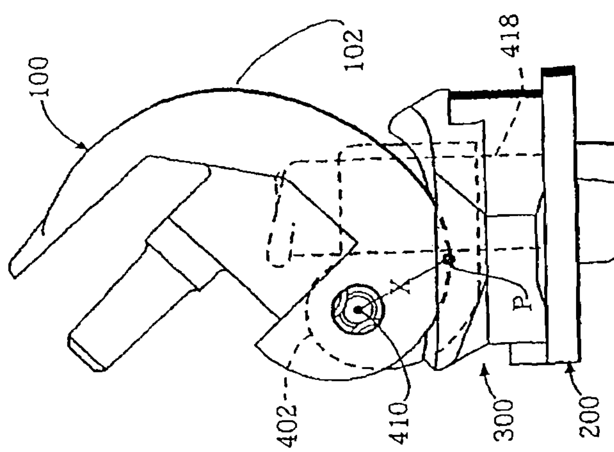

FIG 6B

90° FLEXION

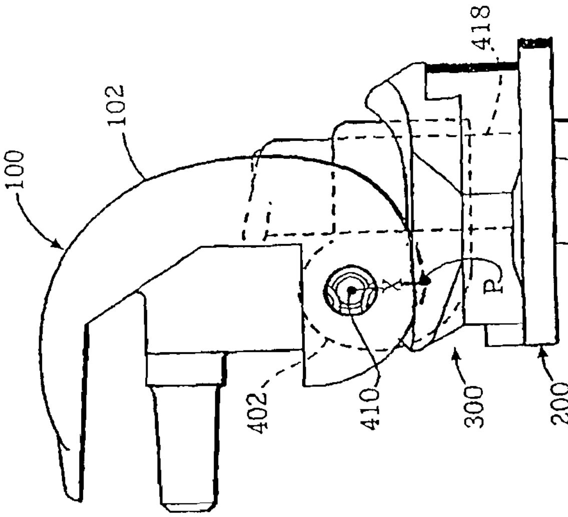

FIG 6C

140° FLEXION

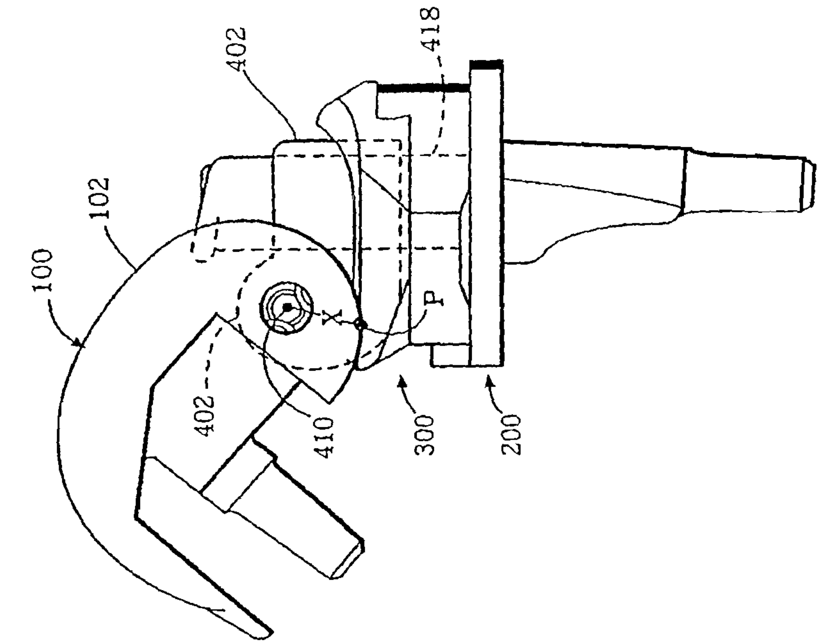

FIG 6E

120° FLEXION

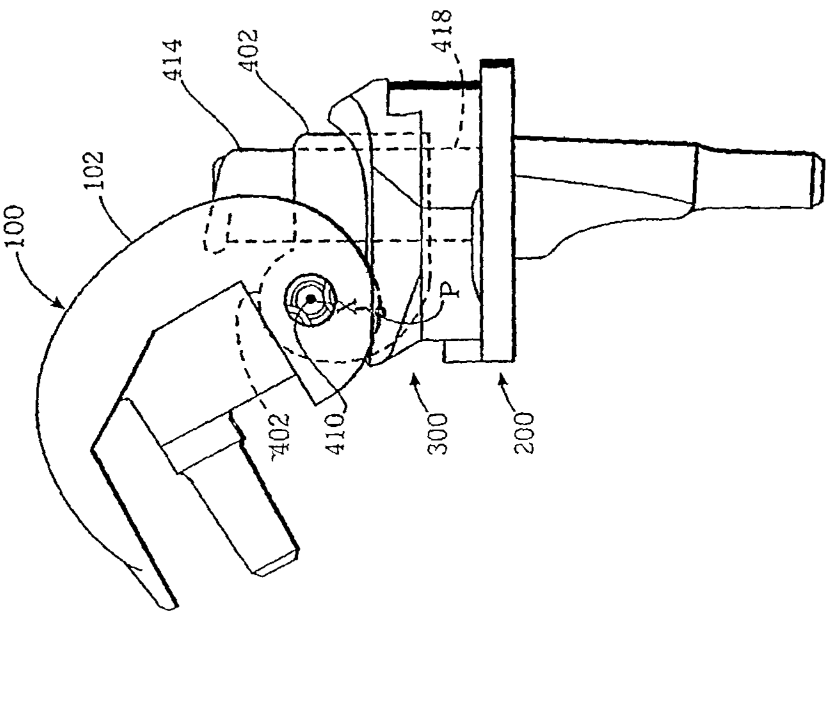

FIG 6D

HINGED JOINT SYSTEM

RELATED APPLICATIONS

This application is a continuation of U.S. Ser. No. 10/499,047 filed Jun. 16, 2004 and titled "Hinged Joint System," now issued as U.S. Pat. No. 7,572,292, which is the U.S. national phase of International Application No. PCT/US02/41221 filed on Dec. 20, 2002 and published in English as International Publication No. WO 03/059203 A1 on Jul. 24, 2003, which application claims the benefit of U.S. Provisional Application No. 60/342,350 filed Dec. 21, 2001 entitled, "Hinged Knee System," the entire contents of each of which are incorporated by reference herein.

FIELD OF THE INVENTION

The present invention relates to prosthetic joints, and more particularly to a hinged joint that allows for the natural kinematics of the joint.

BACKGROUND OF THE INVENTION

In primary knee joint replacement surgery, a surgeon typically affixes two prosthetic components to the patient's bone structure; a first to the patient's femur and a second to the patient's tibia. These components are typically known as the femoral component and the tibial component respectively. In a typical primary knee joint replacement surgery the ligaments and tendons are sufficiently intact to control the movement of the knee.

The femoral component is placed on a patient's distal femur after appropriate resection of the femur. The femoral component is usually metallic, having a highly polished outer condylar articulating surface, which is commonly J-shaped.

A common type of tibial component uses a tray or plateau that generally conforms to the patient's resected proximal tibia. The tibial component also usually includes a stem which extends at an angle to the plateau in order to extend into a surgically formed opening in the patient's intramedullary canal. The tibial component and tibial stem are both usually metallic.

A plastic or polymeric (often ultra high molecular weight polyethylene or UHMWPE) insert or bearing fits between the tray of the tibial component and the femoral component. This tibial insert provides a surface against which the femoral component condylar portion articulates—moves in gross motion corresponding generally to the motion of the femur relative to the tibia.

In some knee prostheses, the tibial insert also engages in motion relative to the tibial tray. Such motion can be translational and-or rotational sliding motion relative to the tibial plateau. In other types of knee prostheses with tibial inserts, the tibial inserts can engage in other types of motion relative to the tibial plateau and-or femoral component.

Revision surgery is required when the primary prosthesis fails. In most revision cases additional stabilization and structure are necessary to compensate for loss of bone and soft tissue. For example, the femoral and tibial components may be thicker to make up for the loss of bone. The femoral component may include a stem, which generally extends at about six degrees from perpendicular from the base portion of the femoral component in order to extend into a surgically formed opening in the patient's intramedullary canal. In order to provide increased stabilization, a box may be provided on the femoral component and a mating post on the tibial component, creating what is called a constrained knee replacement.

In some cases, the loss of soft tissue in the knee requires the use of a linked or hinged knee prosthesis. The three most common indications that a hinged knee is necessary are: (1) in an increasing number of revision cases, the patient loses too much bone and soft tissue to use a constrained knee; (2) an oncologist may be forced to resect a large portion of a bone in order to remove a tumor; and (3) in trauma applications, often the distal femur or proximal tibia has been crushed and must be replaced.

Early hinged knees were fixed, allowing no internal-external rotation. These early hinges had a history of loosening because their fixation could not adequately handle applied forces. Rotating hinges decreased this failure because these rotating hinges minimized internal-external rotational torque. Hinged knee systems provide a physical link of two components with an axle, such that all medial-lateral and anterior-posterior stability is provided by the prosthesis. These systems also address various degrees of bone loss. During normal articulation, the pivot axis for the axle is fixed in the anterior-posterior and superior-inferior directions, so that when the knee is flexed or extended about the axle the center of contact between the femoral and tibial components is fixed. This prevents roll-back.

A major concern with hinged knees is simulating the movement of a natural knee joint. The movement of a natural knee joint has three translations: anterior-posterior, medial-lateral, and inferior-superior and three rotations: flexion-extension, internal-external, and abduction-adduction. The movements of the knee joint are determined by the shape of the articulating surfaces of the tibia and femur and the orientation of the major ligaments of the knee joint, including the anterior and posterior cruciate ligaments and the medial and lateral collateral ligaments as a four linkage system. Knee flexion-extension involves a combination of rolling and sliding of the femur on the tibial plateau called femoral roll-back. In roll-back during flexion, the center of contact between the femur and the tibial plateau moves posteriorly, which allows increased ranges of flexion and increased efficiency of the extensor mechanism.

Current hinged knees typically allow both hinge-over in the flexion-extension direction and internal-external rotation, but do so by flexing about a fixed pivot axis that eliminates roll-back. Some hinged knee designs, on the other hand, have hinge mechanisms that allow roll-back, but do not control roll-back. No known hinged knee systems both allow and control roll-back.

During pre-op planning the extent of bone and soft tissue damage is not always discernable. Since surgical preference typically is to use the least intrusive procedure, a revision with a constrained prosthesis, as opposed to a hinge knee, is preferred. If, during surgery, it becomes apparent that a hinge knee is necessary, it would be preferable for the hinge to be part of an integrated system so the surgeon can proceed with minimal interruptions. Current hinged systems are stand alone, so that if the surgeon plans to use a constrained knee but realizes during surgery that the added constraint of a hinged knee is required, the surgeon cannot switch to a hinged knee during the procedure. Rather, the surgeon typically has to start another procedure resulting in longer operating times and greater risk to the patient. Additionally, current hinged knees require the surgeon to remove a large portion of the patient's bone in order to allow proper implantation.

Current hinged knee systems require a considerable amount of assembly during surgery in order to ensure that the various components are properly sized and connected. Such assembly takes time, is tedious and prone to error, and averts the surgeon's attention from more critical matters directly related to the health of the patient.

Thus, there is a current need for a hinged knee prosthesis that provides natural kinematics without excessive bone removal. There is also a need for a hinged knee system that is compatible with existing total knee replacement systems. Finally, there is a need for a hinged knee system that requires less assembly during surgery.

SUMMARY OF THE INVENTION

Methods, systems, and devices for replacement of a joint with a prosthetic system that replicates the natural kinematics of the joint are disclosed. Methods, systems, and devices according to the invention not only allow, but also control, the roll-back and kinematics of the prosthesis, and thus the joint, and provide both natural biomechanics and joint performance. Some existing hinged knee designs provide linked articulation in substitution for soft tissue deficiencies, but do so by flexing about a fixed pivot axis eliminating roll-back. The prior art that allows movement of the axis of rotation or axle allows the axle to move in the anterior and posterior directions, but does not control the movement. Some prior art discloses an axis of rotation near the center of the femoral component and other prior art discloses an axis of rotation in the rear portion of the femoral component. This prior art allows the femoral component and femur to move in the anterior and posterior directions relative to the tibia, but does not control the movement. The present invention controls roll-back through the operation of its linkage component. A prosthetic system according to one embodiment of the invention includes a tibial component having a tibial plateau and a tibial stem portion, the tibial plateau having a top side and a bottom side, a tibial insert, with a bearing surface, adapted to be positioned on the top side of the tibial plateau, a femoral component having a base portion, a central housing and a femoral stem portion, the femoral component having an axis of extension-flexion rotation, the base portion having a pair of condyles, a mechanical linkage component linking the tibial component with the femoral component and with the tibial insert in between the tibial component and the femoral component, so that there is a center of contact between the condyles and the bearing surface, the mechanical linkage component adapted to allow the center of contact to move posteriorly during flexion, provide for the movement of the axis of extension-flexion rotation in the superior-inferior direction, allow rotation of the tibial component, the tibial insert, and the femoral component about a superior-inferior axis, and offset the axis of extension-flexion rotation from the superior-inferior axis in order to provide and control the natural kinematics of the knee joint.

A prosthetic system according to one embodiment of the invention includes a mechanical linkage component linking the tibial component with the femoral component and with the tibial insert in between the tibial component and the femoral component so that there is a center of contact between the condyles and the bearing surface, the mechanical linkage component adapted to move in the superior-inferior directions and restrained from movement in the anterior-posterior directions, wherein the center of contact between the condyles and bearing surface moves in the anterior-posterior direction as the femoral component moves through extension and flexion.

A prosthetic system according to one embodiment of the invention includes a tibial component having a tibial plateau and a tibial stem portion, the tibial plateau having a top side and a bottom side, a post having a proximal end and a distal end, the post adapted to project from the top side of the tibial plateau, a cap adapted to mount on the proximal end of the post, a tibial insert having an aperture, the tibial insert adapted to be positioned on the top side of the tibial plateau with the tibial insert aperture adapted to receive the post and the cap, a femoral component having a base portion and a central housing having a femoral stem portion, the base portion having a pair of condyles and two posteriorly extending lobes, an axle adapted to connect to the lobes and extend between the lobes, and a link having an anterior end and a posterior end, the link adapted to be connected to the axle at the posterior link end and to receive the post and the cap at the anterior link end.

A method for replacing a joint with a prosthetic system according to one embodiment of the invention includes resecting the proximal end of the patient's tibia to expose the tibial intramedullary canal of the tibia, resecting the distal end of the patient's femur to expose the femoral intramedullary canal, connecting a tibial stem and a femoral stem to a prosthetic system, the prosthetic system having a mechanical linkage component, inserting the tibial stem into the tibial intramedullary canal, and inserting the femoral stem into the femoral intramedullary canal. The method allows a surgeon to convert to the prosthetic system from a primary or revision prosthesis with common bone cuts and instrumentation. The prosthetic system allows the surgeon to select an appropriately sized tibial insert and a cap so that a pre-assembled femoral component can be used, thereby significantly reducing the amount of surgical time devoted to assembly of the knee.

Another feature of the present invention is that a bioresorbable bumper can be placed in the prosthetic system to prevent rotation of the prosthetic components around a superior-inferior axis until the bumper is resorbed by the body.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is an anterior perspective view of an embodiment of the invention showing the prosthetic system in extension.

FIG. **1**B is an anterior perspective view of the embodiment shown in FIG. **1**A, showing the prosthetic system in flexion.

FIG. **2** is a posterior view of an embodiment of the prosthesis.

FIG. **3** is an anterior view of an embodiment of the prosthesis.

FIG. **4** is a top view of an embodiment of the prosthesis.

FIG. **5** is a posterior exploded view of an embodiment of the invention.

FIGS. **6**A-E are side views of an embodiment of the prosthesis progressing from extension in FIG. **6**A to flexion in FIG. **6**E.

DETAILED DESCRIPTION

FIG. **1** illustrates a perspective view of an embodiment of a prosthetic system in extension in FIG. **1**A and at 90° flexion in FIG. **1**B. FIGS. **2** and **3** show a posterior view and an anterior view, respectively, of an embodiment of the prosthetic system in extension. FIG. **4** shows a top view of an embodiment of the prosthetic system in extension. While the illustrated embodiment is a knee joint, the present invention could be used in other joints, such as a hip joint or a shoulder joint. The prosthetic system includes a femoral component **100**, a tibial component **200**, a tibial insert **300**, and a mechanical linkage component or hinge portion **400**. In surgery with the prosthetic system, the tibia and femur are recessed with the intramedullary canals of the tibia and the femur surgically prepared to receive stems. The present invention requires the same bone cuts and instrumentation as a primary or revision system, such as, for example, the Genesis II total knee system from Smith & Nephew. Only one additional cut is necessary with the present invention.

The tibial component **200** includes a tibial plateau **202** and a tibial stem portion **204**. The tibial stem portion **204** includes a generally cylindrical portion **206** integrally formed with distal end **208** which comprises a Morse taper. The distal end **208** can have a long stem attached (not shown) via the Morse taper in a manner well known to those skilled in the art. Distal end **208** is fitted into the intramedullary canal of the resected tibia, either with or without a long stem attached to the Morse taper.

The femoral component **100** includes a pair of condyles **102**, which are metallic and highly polished and formed on a base portion **103** of the femoral component **100**. The condyles **102** engage with the tibial insert **300**. The femoral component **100** has a J-shaped cross section and as a result has J-shaped condylar surfaces **102**. These J-shaped surfaces have at least two different radii of curvature: a distal radius and a posterior radius. In the preferred embodiment shown, the distal radius of curvature is larger than the posterior radius of curvature. The base portion **103** includes a pair of posteriorly extending lobes **104** that connect to the hinge element **400** as described below. Integral with and positioned between the condylar portions is a central housing **106** having a top wall **108** and side walls **110**. Angularly mounted from the top wall **108** is a femoral stem portion **112** having a proximal end **114** comprising a Morse taper. The proximal end **114** can have a long stem attached (not shown) via the Morse taper in a manner well known to those skilled in the alt, or can be used without a long stem. The proximal end **114** of the stem portion **112** is inserted into the intramedullary canal of the resected femur, either with or without a long stem attached to the Morse taper.

For simplicity, the preferred embodiment is described as having two radii of curvature along the distal and posterior surfaces of femoral component **100**, with the distal radius being larger than the posterior radius, as discussed above. It is to be understood that it may be advantageous to incorporate one or more additional radii of curvature along the outer surface of the femoral component. In particular, a third radius may be used to form the curvature at the proximal surface of lobes **104** of the posterior condyles. The number and relationship of the radii of curvature may be varied without departing from the spirit and scope of this invention.

FIG. **5** is an exploded posterior perspective view of an embodiment of the prosthetic system. A post **210** is positioned on the top side of the tibial plateau **202** in the vertical (superior-inferior) direction perpendicular to the tibial plateau **202** and a stop **212** is positioned at the posterior portion of the tibial plateau **202**. The post **210** receives a cap **414**. The cap **414** is secured to the post **210** via a fastener **420** or any other method known to those skilled in the art.

The tibial insert **300** has a top bearing surface **302** and a recessed portion **304** with an aperture **306** and a notch **308**. The tibial insert aperture **306** receives the tibial post **210** and cap **414** so that the tibial insert **300** is situated on the tibial plateau **202**. In the illustrated embodiment, the tibial insert rotates about the vertical (superior-inferior) axis. The rotation of the tibial insert is controlled by the notch **308** at the posterior of the tibial insert **300** and the stop **212** of the tibial plateau **202**. The condyles of the femoral component translate on the bearing surface **302** of the tibial insert **300**.

The hinge portion **400** includes a link **402** with an aperture **404** in the medial-lateral direction on the posterior end and an aperture **406** in the superior-inferior direction on the anterior end. Two bushings **408** fit into the ends of the posterior aperture **404**. The posterior end of the link **402** is positioned between the lobes **104** of the femoral component **100**. The link **402** is rotatably connected to the femoral component by an axle **410** positioned in apertures **105** of both lobes **104** of the femoral component **100** and through the posterior aperture **404** and bushings **408** of the link. The axle **410** is secured to the lobes **104** via two axle clips **412** on each end of the axle **410**. Alternatively, the axle **410** could be secured to the lobes **104** via any method known to those skilled in the art. The anterior aperture **406** of the link receives the tibial post **210** and cap **414**. The link **402** translates up and down the post **210** and cap **414** and rotates about the superior-inferior axis. The cap **414** has a sheath portion **418** and a lip portion **416** that is positioned at its proximal end. Alternatively, the cap **414** could fit only on the top of the tibial post **210** and not have a sheath portion. The anterior aperture **406** of the link **402** has a smaller diameter in its distal half so that the lip **416** of the cap **414** catches on the smaller diameter and controls the translation of the link **402**.

The cap **414** is a separate piece and different sizes are available to correspond with the thickness of the tibial insert **300**. This allows the femoral component to be pre-assembled and allows the surgeon to select the appropriate cap size and tibial insert size during surgery to allow for proper operation of the prosthetic system. This differs from most systems where the surgeon must assemble the femoral component based on the tibial insert size.

As demonstrated by FIG. **6**, the operation of the hinge portion **400** allows femoral roll-back and controls this movement. FIG. **6** shows the prosthetic system moving from full extension (0° flexion) in FIG. **6**A to 140° flexion in FIG. **6**E. The prosthetic system is in 45° flexion in FIG. **6**B, 90° flexion in FIG. **6**C, and 120° flexion in FIG. **6**D. As shown in FIG. **6**A, when the knee is in extension the link **402** is towards the top of the tibial post **210** and cap **414**. Distraction is prevented by the cap **414** of the tibial post **210** catching on the inner diameter of the anterior link aperture **406**. As the knee moves from extension to flexion the link **402** moves down the tibial post **210** and cap **414**. The link **402** does not move in the anterior-posterior directions, which allows the axle **410** to move only along the superior-inferior axis.

As shown in FIG. **6**, the axle moves in the inferior direction when the knee moves from extension to flexion and moves in the superior direction when the knee moves from flexion to extension. Axle **410** moves inferiorly until posterior movement of the femoral component **100** positions femoral component **100** so that it rides up the posterior lip of tibial insert **300**, then axle **410** moves superiorly. In the embodiment shown, this translates into inferior movement of axle **410** when the knee move from 0° to about 90° flexion, no vertical movement of axle **410** from about 90° to about 120°, and superior movement from about 120° to about 140° flexion. The exact motion of axle **410** through the range of knee flexion may change depending on the size of the components and other design features not critical to this invention.

The center of contact of the condyles **102** on the bearing surface **302** moves in the posterior direction as the knee moves from extension to flexion and moves in the anterior direction when the knee moves from flexion to extension. In FIG. **6**, P represents the center of contact of the condyles and the bearing surface. Because the radius of curvature of the condyles decreases when the knee moves from extension to flexion, the distance X from the center of contact P to the center point of the axle decreases from extension to flexion, up to about 120° of flexion in the embodiment shown.

The freedom of the axle **410** to move superiorly-inferiorly while linking the femoral and tibial components via the link **402** and the offset of axle **410** relative to the center of rotation of the femoral component **100** result in roll-back of the femoral component during flexion while maintaining contact between the femoral component and the tibial insert **300**. Increasing the posterior offset of the axle **410** from the center of rotation of the femoral component **100** causes an increasing anterior shift in the center of contact P between the femoral component **100** and the tibial insert **300** in extension and increasing travel of the link **402** down the post **210** and cap **414** in flexion. Increasing inferior offset of the axle **410** from the center of rotation of the femoral component **100** causes an increasing posterior shift in the center of contact between the femoral component and the tibial insert in flexion and decreasing travel of the link **402** up the post **210** and cap **414** in extension.

The ability of the link **402** to travel superiorly-inferiorly on the tibial post **210** and cap **414** allows specific combinations of link length, anterior-posterior offset and superior-inferior offset of the axle **410** so that the anterior-posterior location of the center of contact between the femoral component and the tibial insert as a function of flexion can be specified and controlled. For example, less roll-back may be desirable for smaller sized knees. This motion is further tailored by combining the above described movement with the two different radii of curvature (larger distally and smaller posteriorly) in the condyle section of the femoral component—illustrated by decrease of the distance X as the knee moves from extension to flexion in FIG. **6**. Depending on the specific objectives regarding the occurrence of roll-back during flexion, a hinge knee could be designed according to this invention having a single radius of curvature on the femoral component, or two or more radii of curvature. While two radii are shown in the preferred embodiment, it is to be understood that the principles of this invention are not to be so limited.

In specifying the motion as a function of flexion (kinematics), the performance of muscle and other soft tissues can be optimized. For example, femoral roll-back is recognized as improving efficiency of the extensor mechanism. In general, roll-back is a posterior shift in the center of contact of the femoral component on the tibial component as the knee flexes and an anterior shift in the center of contact of the femoral component on the tibial component as the knee extends. Three parameters define and control kinematics, including roll-back, in the prosthetic system of the current invention. The first parameter is the anterior-posterior and superior-inferior placement of the axle in the femoral condyles. With the first parameter, the axis of rotation is positioned in the posterior portion of the femoral component, without imposing undue structural load away from the natural load axis of the knee bone structure. This way the load axis is not skewed in the anterior-posterior or medial-lateral direction from natural load axis of tibia. The second parameter is the two different radii of curvature in the J-curve section of the femoral component. The third parameter is the length of the link. Tailoring these parameters according to the implant type and size optimizes the kinematics and joint performance and allows control of roll-back.

The prosthetic system additionally does not allow subluxation in the medial-lateral directions or in the anterior-posterior directions, because the tibial component is mechanically linked to the femoral component.

The prosthetic system according to one embodiment shares common design elements of a primary and revision system, such as the Genesis II from Smith & Nephew or other total knee system. This allows a surgeon to intra-operatively convert from a primary or revision implant to a hinged implant with common bone cuts and the same instrumentation rather than utilizing a separate system and instruments. The prosthetic system according to one embodiment requires only three additional cuts than are required in a typical revision knee replacement procedure. The extra cuts are needed to accommodate the wider central housing of the femoral component used in the present invention, change the tibial plateau to a neutral (0°) slope, and accommodate the axle. Even with these few additional cuts, the system according to this invention provides relatively simple intra-operative conversion from a standard revision knee to a hinged knee. The prosthetic system according to one embodiment utilizes a pre-assembled femoral component, so that the surgeon does not have to assemble a femoral component based on the tibial insert. The tibial plateau of the present invention can accommodate several thicknesses of tibial inserts enabling the surgeon to choose a tibial insert of appropriate thickness and corresponding cap and use a pre-assembled femoral component. Allowing conversion to the hinge knee of the present invention intra-operatively reduces the risk to the patient by reducing the procedure time.

The prosthetic system according to one embodiment is designed to accept body segments to replace the entire bone in the area of the knee (femur or tibia) in the case of tumor resections or trauma. Such body segments may be secured to the Morse tapers on stem portions **204** and/or **112** in a generally conventional manner or by any other attachment means known in the art. If an additional prosthesis is required for replacement of bone, it is provided as a separate component.

In general, an implant is unstable for several weeks after surgery because there is no scar tissue in the joint envelope. During this time, which typically lasts approximately six weeks but can vary considerably from one patient to the next, it is desirable to not allow rotation along the superior-inferior axis. In an embodiment of the prosthetic system, a bioresorbable bumper **600** (shown in FIG. **5**) is placed in the gap of the tibial insert **300** in between the notch **308** and the stop **212** of tibial plateau. This allows an implant to be fixed when implanted, but later allows the implant to rotate as the material is resorbed by the body. The rate of resorption can be selected by choosing the correct composition for bumper **600** to meet the particular needs of the patient.

One embodiment according to this invention is a prosthetic system and kit of parts for replacement of joints, such as a knee. Along with the components described above, the kit of parts includes cutting blocks, reamers, and trials.

One method of using the prosthetic system according to this invention for replacing a joint, such as a knee, is as follows:

(1) resect the proximal end of the tibia to expose the tibial intramedullary canal of the tibia;

(2) resect the distal end of the femur to expose the femoral intramedullary canal;

(3) connect the tibial stem and the femoral stem to the prosthetic system;

(4) insert a femoral stem into the femoral intramedullary canal; and

(5) insert a tibial stem into the tibial intramedullary canal.

This method additionally includes selecting the appropriate tibial insert and cap intra-operatively.

In an alternative embodiment, the mechanical linkage component can be used in other joints allowing the axis of rotation of the joint to translate in order to provide controlled roll-back and natural kinematics during flexion or extension of the joint.

The disclosure of systems and processes as recited above is not intended to limit the scope of the present invention. Various linking mechanisms can be used that allow the center of contact between the condyles and the tibial insert to move posteriorly during flexion, provide for the movement of the axis of extension-flexion rotation in the superior-inferior direction, allow and control rotation about the superior-inferior axis, and offset the axis of rotation from the superior-inferior axis in order to provide the natural kinematics of the knee joint or other joint.

What is claimed is:

1. A hinged knee prosthesis, comprising:

(a) a femoral component, the femoral component comprising medial and lateral condylar articulating surfaces;

(b) a tibial component, the tibial component comprising medial and lateral articulating surfaces for articulating with the medial and lateral condylar articulating surfaces of the femoral component; and

(c) a mechanical linkage connecting the femoral component to the tibial component;

wherein the mechanical linkage, when connecting the femoral component to the tibial component, defines a flexion-extension axis about which the femoral component can rotate with respect to the tibial component; and

wherein, when the mechanical linkage is connecting the femoral component to the tibial component and the medial and lateral condylar articulating surfaces of the femoral component are in contact with the articulating surfaces of the tibial component, articulating the hinged knee prosthesis from an extended orientation to a flexed orientation causes:

(i) the flexion-extension axis to move in a superior to inferior direction while not moving in an anterior-posterior direction; and

(ii) a lateral center of contact between the lateral condylar articulating surface of the femoral component and the lateral articulating surface of the tibial component to move in an anterior to posterior direction.

2. The hinged knee prosthesis of claim **1**, wherein, when the mechanical linkage is connecting the femoral component to the tibial component and the medial and lateral condylar articulating surfaces of the femoral component are in contact with the articulating surfaces of the tibial component, articulating the hinged knee prosthesis from the extended orientation to the flexed orientation causes a medial center of contact between the medial condylar articulating surface of the femoral component and the medial articulating surface of the tibial component to move in an anterior to posterior direction.

3. The hinged knee prosthesis of claim **2**, wherein, when the mechanical linkage is connecting the femoral component to the tibial component and the medial and lateral condylar articulating surfaces of the femoral component are in contact with the articulating surfaces of the tibial component, articulating the hinged knee prosthesis from the extended orientation to the flexed orientation causes the flexion-extension axis to move towards the medial and lateral centers of contact.

4. The hinged knee prosthesis of claim **3**, wherein the medial condylar articulating surface includes at least one curved medial surface and the lateral condylar articulating surface includes at least one curved lateral surface, and, when the mechanical linkage is connecting the femoral component to the tibial component, the flexion-extension axis is positioned eccentrically with respect to the medial and lateral surfaces.

5. The hinged knee prosthesis of claim **4**, wherein at least one of the medial and lateral condylar articulating surfaces of the femoral component is a J-shaped surface.

6. The hinged knee prosthesis of claim **5**, wherein the J-shaped surface defines at least two different radii of curvature along distal and posterior portions of the J-shaped surface.

7. The hinged knee prosthesis of claim **1**, wherein the mechanical linkage comprises an axle associated with the femoral component, a post associated with the tibial component, and a link connecting the axle to the post.

8. The hinged knee prosthesis of claim **7**, wherein the axle extends along the flexion-extension axis.

9. The hinged knee prosthesis of claim **8**, wherein the link connects to the axle at a posterior end of the link and to the post at an anterior end of the link.

10. The hinged knee prosthesis of claim **9**, wherein the link can move along the post in superior and inferior directions.

11. The hinged knee prosthesis of claim **9**, wherein the axle extends through a posterior aperture in the link and the post extends through an anterior aperture in the link, the anterior and posterior apertures extending substantially perpendicular relative to one another.

12. The hinged knee prosthesis of claim **11**, wherein the posterior aperture of the link extends along the flexion-extension axis and the anterior aperture of the link extends along a superior-inferior axis.

13. The hinged knee prosthesis of claim **1**, wherein, when the mechanical linkage is connecting the femoral component to the tibial component and the medial and lateral condylar articulating surfaces of the femoral component are in contact with the articulating surfaces of the tibial component, articulating the hinged knee prosthesis from an extended orientation to a flexed orientation causes the lateral center of contact between the lateral condylar articulating surface of the femoral component and the lateral articulating surface of the tibial component to move in an anterior to posterior direction relative to the flexion-extension axis.

14. A knee prosthesis comprising:

(a) a femoral component comprising a pivot connector, a medial condylar surface that defines a first arc that is eccentric relative to the femoral component pivot connector, and a lateral condylar surface that defines a second arc that is eccentric relative to the femoral component pivot connector;

(b) a tibial component comprising a medial articulating surface and a lateral articulating surface; and

(c) a mechanical linkage for connecting the femoral component to the tibial component; wherein, when the femoral component is connected to the tibial component by the mechanical linkage:

(i) the mechanical linkage is connected to the pivot connector of the femoral component to define a pivot axis of the femoral component about which the femoral component can articulate relative to the tibial component, the pivot axis extending from a medial side of the femoral component to a lateral side of the femoral component;

(ii) the mechanical linkage allows movement of the pivot axis in superior and inferior directions as the femoral component articulates relative to the tibial component;

(iii) the mechanical linkage prevents movement of the pivot axis in anterior and posterior directions as the femoral component articulates relative to the tibial component; and

(iv) the femoral component medial condylar surface contacts the tibial component medial articular surface at a medial contact point and the femoral component lateral condylar surface contacts the tibial component lateral articular surface at a lateral contact point such that the pivot axis will move towards at least one of the medial and lateral contact points as the femoral component articulates relative to the tibial component from an extended orientation to a flexed orientation and such that at least one of the contact points will move in an anterior to posterior direction relative to the pivot axis as the femoral component articulates relative to the tibial component from the extended orientation to the flexed orientation.

15. The knee prosthesis of claim **14**, wherein, when the femoral component is connected to the tibial component by the mechanical linkage, the mechanical linkage does not substantially constrain at least one of internal and external rotations of the femoral component relative to the tibial component as the femoral component articulates relative to the tibial component.

16. The knee prosthesis of claim **14**, wherein the mechanical linkage prevents movement of the pivot axis in anterior and posterior directions relative to the femoral component.

17. The knee prosthesis of claim **14**, wherein the mechanical linkage prevents movement of the pivot axis in anterior and posterior directions relative to the tibial component.

18. The knee prosthesis of claim **17**, wherein the mechanical linkage allows rotation of the pivot axis relative to the tibial component about a superior-inferior axis.

19. A knee prosthesis comprising:

(a) a femoral component comprising a pivot connector, a medial condylar surface that defines a first arc that is eccentric relative to the femoral component pivot connector, and a lateral condylar surface that defines a second arc that is eccentric relative to the femoral component pivot connector;

(b) a tibial component comprising a medial articulating surface and a lateral articulating surface; and

(c) a mechanical linkage for connecting to the pivot connector of the femoral component and for connecting to the tibial component;

wherein, when the mechanical linkage is connected to the tibial component and to the pivot connector of the femoral component, and when the medial and lateral condylar surfaces of the femoral component are in contact with the medial and lateral articulating surfaces of the tibial component, articulating the femoral component relative to the tibial component from an extended orientation to a flexed orientation causes the pivot connector of the femoral component to move towards the tibial component while retaining an anterior-posterior position of the pivot connector relative to the tibial component.

20. The knee prosthesis of claim **19**, wherein the pivot connector comprises an axle associated with the femoral component.

21. The knee prosthesis of claim **19**, wherein the pivot connector comprises structure associated with the femoral component for connecting to an axle.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,545,570 B2
APPLICATION NO. : 12/353295
DATED : October 1, 2013
INVENTOR(S) : Crabtree et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page:

The first or sole Notice should read --

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1271 days.

Signed and Sealed this
Seventeenth Day of February, 2015

Michelle K. Lee
Deputy Director of the United States Patent and Trademark Office